

VERTEBRATE INVASIONS IN CHILE: AN INVITATION TO COLLABORATION

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Abstract: Chile is an interesting country for the study of biological invasions because it is flanked by biogeographical barriers on all sides. Therefore, it should be relatively immune from invasions. Indeed, the incidence of invasive species in regions comparable to Chile (California, mediterranean Europe, South Africa, mediterranean Australia) is generally higher, except for mammals. The most likely cause of the high incidence of invading mammals is their previous introduction to Argentina and subsequent spread from there toward Chile, crossing the Andes Ranges. Thus, this supposed barrier to immigration is ineffective. I analyze four invasive species that Chile shares with the United States (US) and/or Canada: African clawed frog (*Xenopus laevis*), California quail (*Callipepla californica*), American beaver (*Castor canadensis*), and European rabbit (*Oryctolagus cuniculus*). I introduce three main topics on which collaborative work could be initiated between US and Chilean researchers: (1) invasion pathways, spread rates, and environmental impact of shared species, (2) comparative ecology of shared species, and (3) genetic diversity of populations of shared species.

Key Words: biogeographical barriers, California, Canada, Chile, collaborative work, invasive species, mediterranean-type regions, shared species, species translocations, United States.

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AN ISOLATED COUNTRY THAT IS NOT

Chile is an interesting country for the study of biological invasions: it is not only long and narrow but is flanked by strong biogeographically barriers on all sides (Atacama desert to the north, Andean Ranges to the east, Pacific Ocean to the west) and is separated from other southern continents by broad oceans, the Pacific and the Atlantic (Jaksic 1998, Figueroa et al. 2004). Nevertheless, Chile currently hosts at least one invasive species of each amphibians and reptiles (2.4% and 1.1% of the respective native species), seven of birds (1.8% of the total number of native bird species), and 15 invasive mammals (accounting for 15.2% of the respective native species). Thus, this assumedly isolated country is not immune from being invaded.

The raw numbers and percentages quoted above do not seem too impressive, but may be misleading. It makes more sense to compare the incidence of invasive birds and mammals in regions climatically and vegetationally similar to Chile. For instance, California, southern Europe, South Africa, and southern Australia, the so-called mediterranean regions of the world (Jaksic 1998, Figueroa et al. 2004). In comparison to these similar regions,

Chile has relatively few invasive birds (2.7% in mediterranean Chile versus 3.5% in mediterranean Europe, and 6.7% in mediterranean California). But it does have more invasive mammals (7.5% in mediterranean Chile versus 5.6% in mediterranean California). The most likely cause of the high incidence of invading mammals in Chile is their previous introduction to Argentina and subsequent spread from there toward Chile, crossing the Andes Ranges (Jaksic et al. 2002, Iriarte et al. 2005). This conveys the lesson that even a very tall mountain range is not barrier enough for invading mammals.

All of this general information has been published in previous papers cited above. Chile, Canada, and the US share several species in common, among them, monk parakeet (*Myiopsitta monachus*), muskrat (*Ondatra zibethicus*), nutria (*Myocastor coypus*), feral pig (*Sus scrofa*), and American mink (*Mustela vison*). Here, I will refer to other four species that Chile shares with the United States (US) and Canada as invaders in that country, with the aim of eliciting interest in collaboration between the respective country scientists.

FOUR INVADING VERTEBRATES IN CHILE

African clawed frog, *Xenopus laevis*

There is only one amphibian invader in Chile, the African clawed frog. This species was introduced to a lagoon close to the international airport of Santiago in 1973, and then spread out in all directions except towards the Andes mountains (Jaksic 1998, Lobos and Jaksic 2005). This invasion wave has traveled over 500 km in 34 years which is equal to 15 km/year! But this is an overestimate, because there have been many intentional translocations. African clawed frogs reach from almost sea level up to 620 m and are present more often in lagoons (94% of sites) than in rivers (60% of sites). With regard to lagoons, they are present mostly in irrigation dams (80% of occurrences) than in natural lagoons (20%). African clawed frogs inhabit quite a diverse array of habitats with regards to water temperature, dissolved oxygen, pH, and electric conductivity, indicating a high degree of adaptability and further invasion potential. In central Chile, African clawed frogs prey on essentially three major food types: insects, mollusks and crustaceans, with *Xenopus* larvae being the only vertebrates found in local diets. It has been hypothesized that the African clawed frog is little preyed upon because of its toxic skin. But we have quantitative records that at least three Chilean native bird species prey on clawed frogs with the main predator being night heron (*Nycticorax nycticorax*), but also kelp gull (*Larus dominicanus*) and burrowing owl (*Speotyto cunicularia*). The African clawed frog is considered to be completely aquatic at all stages of its life history, but we have quantitative records of overland migration during nighttime, which increases its invasive potential.

California quail, *Callipepla californica*

The exact distributional range of California quail in Chile is unknown, but it is found from at least Antofagasta (Chile's II Region) to Puerto Montt (X Region) and also in oceanic Robinson Crusoe Island (offshore from the V Region). The history of introductions and translocations of this species is quite interesting (Jaksic 1998, Swarth 1927). It appears to have been introduced from California to at least two different parts of Chile on different occasions during the 1860s and 1880s. According to Swarth (1927), William Groves brought a dozen quail from San Jose, California, to

Limache (Chile's V Region) in 1864, and kept them caged until all escaped, establishing a population in the wild. Later, C. J. Lambert imported quail from San Francisco, California, and released them to the wild in La Serena (Chile's IV Region) in 1881 or 1882. In an unexpected twist, quail were reintroduced from Chile back to California in the 1920s. Indeed, F. E. Booth bought quail in Santiago (Metropolitan Region) and shipped them back to San Francisco, where a first batch of 134 quail arrived in January 1927 and was sent to a game reserve in Sonoma county. The paper reporting all this information (Swarth 1927) was submitted for publication on February 9, 1927, and thus, it is possible that other "Chilean" quail may have been shipped back to California! Perhaps this could be traced using genetic markers.

American beaver, *Castor canadensis*

The American beaver was first introduced from around the Toronto area of Canada to the Argentinean side of Tierra del Fuego Island in 1946 (Jaksic 1998, Jaksic et al. 2002, Iriarte et al. 2005, Wallem et al., In Press). From their release site, American beaver expanded toward the Chilean half of the island and to the rest of the Fuegian archipelago. This species was thought to be confined to the south of the Straits of Magellan, but there are credible reports of its presence on the mainland (Wallem et al., In Press). This invasion wave has traveled at 3-6 km/year depending on direction, over the last 60 years. The population growth of the American beaver has been so explosive that both the Argentinean and Chilean governments are attempting to control this species, primarily because the beaver causes extensive damage to the native *Nothofagus* forests (Iriarte et al. 2005).

European rabbit, *Oryctolagus cuniculus*

European rabbits were first introduced to central Chile in 1884, to an island in a lake (Cauquenes), from where they escaped when a drought enabled connection of the island with the mainland (Jaksic 1998). From this release point, rabbits expanded their distribution toward the north and south of the country. They also crossed the Andean Ranges toward Argentina and have continued their expansion there (Jaksic et al. 2002). This invasion wave has traveled at 7-16 km/year over the last 120 years. The negative effects of European rabbits on native vegetation and flora, both herbaceous and shrubby, are well documented (Jaksic 1998). The rabbit forestalls secondary succession of the

Chilean scrublands, rendering them more open and favoring their invasion by invasive herbs, mostly of Eurasian origin. At the same time, the case of the European rabbit is one of the most convincing examples of a positive effect of some invaders (Jaksic 1998). It has been documented that in less than 16 years, the native Culpeo fox (*Pseudalopex culpaeus*), Chilean eagle (*Geranoaetus melanoleucus*), and Magellan horned owl (*Bubo magellanicus*) have substantially increased their consumption of European rabbits. Therefore, the addition of this new prey resource can be considered beneficial for at least three native endangered predators.

PROSPECTS FOR COLLABORATION

I foresee three main topics on which collaborative work could be initiated between US, Canadian, and Chilean researchers. First, invasion pathways, spread rates, and environmental impact of invaders could be studied. Parallel studies could be conducted on African clawed frog (Chile versus California) and European rabbit (Chile versus Hawaii). Second, the comparative ecology of invaders could be studied. For instance, African clawed frog (Chile versus California), California quail (Chile versus California), American beaver (Chile versus northeastern US and southeastern Canada) and European rabbit (Chile versus Hawaii) could be compared. Third, genetic diversity of populations of invaders could be studied. For instance, African clawed frog (Chile versus California versus South Africa), California quail (Chile versus California), American beaver (Chile

versus northeastern US and southeastern Canada) and European rabbit (Chile versus Hawaii) could be compared. Chile's Center for Advanced Studies in Ecology and Biodiversity could be a focal point in coordinating such research efforts.

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